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Research on New Roadside Filling Materials and Engineering Application

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ABSTRACT

To solve the problems of high labor intensity, and difficulty in controlling the quality of traditional filling materials filling systems, a one-component lane-side filling material with better load-bearing performance has been developed with corresponding filling equipment and process. In order to grasp the engineering performance of the filling material, orthogonal experimental method was adopted to test the basic performance of the bearing layer material, and the influence of various factors such as water-cement ratio and additives on the initial and final solidification time, reaction temperature and compressive strength of the slurry was investigated through the method of analysis of extreme difference. The results show that: the water-cement ratio has a greater impact on the four performance indicators; the mixing of appropriate amount of quick-setting agent can accelerate the slurry setting rate and reaction temperature; the mixing of early-strength agent and fibre can improve the early compressive strength and toughness of the specimen; comprehensive analysis of the third group of specimens under the load-bearing layer materials with quick-setting, early-strength characteristics, setting time of 9 minutes or less, the maximum compressive strength of 23.3MPa. At the same time, after the simulation test of the specimen with different support schemes, it was found that the integrity and stability of the filling body was improved under the joint restraint of tensile reinforcement, steel ladder beams and reinforcing mesh in the specimen of group D-4. The final on-site monitoring results show that: the displacement of the roadway surface increases after the roof collapses, in which the maximum amount of roof subsidence is 139mm, and the maximum amount of the two gangs approaching is 40mm, and the hollow area tends to be stable under the support of the filling body after compaction, which will ensure the safety of the next working face when it is being mined back.

KEYWORDS

Gob-side entry retaining; Roadside backfilling; Filling material; Support parameters; Top cutting and unloading pressure

1. INTRODUCTION

Gob-side entry retaining is an important technology of Pillarless mining, which has the advantages of high recovery rate of resources, alleviating the tension of mining replacement, realizing Y-shaped ventilation and eliminating the gas overrun at the upper corner [1-2]. At present, the related technology has been widely used in China, forming a variety of forms, such as roof cutting and pressure relief automatic roadway, flexible formwork concrete filling roadway, high water material roadside filling roadway and so on. Among them, the roof cutting pressure relief automatic roadway does not need roadside filling, roof collapse automatic roadway, this form has the advantages of low cost and simple process, but under the conditions of high gas and easy natural coal seam, the air leakage of goaf has great potential safety hazards, which limits the application of this technology, in order to solve the air leakage problem of goaf, the roof cutting pressure relief and roadside filling are combined. The gob-side entry retaining mode [3-4] of "roof cutting and pressure relief + roadside filling" has been formed. At present, the main roadside filling materials are concrete and high-water materials. Concrete roadside filling materials have the advantages of high strength of filling body and low cost of filling materials, but they also have significant disadvantages such as complex filling system, complex process, large material consumption, high labor intensity and short transportation distance. High-water material filling has the advantages of small bearing capacity, simple system, less equipment investment, less material consumption and long-distance transportation. However, high-water material is a two-component material. When used, two kinds of slurry need to be matched by 1:1 volume. Two groups of mixing and pulping equipment and transportation pipelines need to be arranged. The number of equipment is large, the number of people is large, and the filling quality is difficult to control [5-7]. Therefore, the research and development of a single-component roadside filling material with better bearing performance, as well as supporting filling equipment and technology, will provide a more effective supplement for the technology of gob-side entry retaining by roof cutting and pressure relief in high gas and easy natural coal seams.

Zhang Zizheng, Bai Jianbiao et al. [8] analyzed the main types and control mechanism of gob-side entry retaining technology in China, and found that the mechanical and deformation characteristics of the filling material of the supporting body beside the gob-side entry retaining can not adapt to the working face with deep and strong mine pressure, so it is necessary to improve the mechanical properties of the filling material of the supporting body to make it suitable for the complex mining conditions such as deep and strong mine pressure. Under the special mining conditions of the thin coal seam with double soft roof and floor, Jufeng and Sun Qiang [9] put forward the scheme of "pre-building gangue bags in the goaf, timely building cemented filling body in the roadway and lagging reinforcement support in the cemented roof beam and single pillar roadway", which realized the rapid gob-side entry retaining and provided reference experience for the control of complex roof surrounding rock. Sun Lei, Cao Yue et al. [10] studied the influence of double-layer filling body (concrete-high water material combination) on the roof of working face and roadside support through proportioning experiments. The stress-strain curve shows that the filling body can have yield effect and certain compressive strength only when the proportion of high water material is less than 20%. The practical application in Zhangcun Coal Mine has achieved good results. Chen Yong [11-12] studied the problem of large deformation of the filling body beside the roadway with high-water materials, and reinforced the filling body by laying tension bolts, steel mesh and other components to make it better adapt to the severe deformation of the surrounding rock of the roadway.

The above research is mainly aimed at the analysis of the performance of roadside filling materials and the field situation. On this basis, the orthogonal experiment of the new filling material ratio design is carried out, and the effect of each factor level on the four indicators is analyzed by the range method, and the optimal ratio is finally selected. Different supporting measures are applied to the optimal proportion sample to improve its integrity and stability. Finally, the feasibility of materials and processes is verified by engineering cases.

2. NEW ROADSIDE FILLING MATERIAL

2.1. Principle of Proportioning of Filling Materials

The proportioning principle of filling materials refers to reasonably determining the proportioning ratio of various filling materials according to the engineering requirements and material properties during filling engineering. The purpose of the proportioning principle is to ensure that the filling body has the required mechanical properties, stability and durability. According to the technical characteristics of the gob-side entry retaining with side filling of the roof cutting and pressure relief roadway, the proportioning of the filling materials shall meet the following characteristics:

(1) Single-component pure inorganic materials. The pulping and conveying process of single-component materials is simple. The stable performance of materials can be ensured only by mastering the water-cement ratio. At the same time, safe and environmentally friendly inorganic materials must be used to prevent secondary potential safety hazards in the filling process.

(2) Quick setting and early strength characteristics. The material has quick setting and early strength characteristics, which can relieve the pressure on the filling template. Flexible mold can be used to simplify the filling process. In addition, it can also quickly form a supporting role for the roof.

(3) Good bearing performance, the filling body should have a certain yield performance to meet the dynamic load in the process of roof collapse, and should also have a certain bearing performance to control the subsidence of the roof.

(4) Isolation function: timely close and isolate the goaf to prevent air leakage and spontaneous combustion of coal seam, and prevent harmful gases in the goaf from entering the working space.

2.2. Proportion of Filling Materials

(1) Material proportion of that laminate

About 200 ~ 300 mm of the top filling body is made of foaming material, which can actively expand to reach the roof and improve the sealing effect of the goaf. The compressibility of the material produces a pressure relief effect in the process of filling the wall, and the bearing layer provides a higher bearing capacity after the pressure relief to a certain extent.

As the inorganic foam material has a high foaming rate, it shall be adjusted according to the site. The construction water-cement ratio is set as (1.5 ~ 2.5), and its curing time, gelling time, uniaxial compressive strength (1 d, 7 d, 28 d) and expansion rate of materials with different water-cement ratios are measured in the laboratory. The results are shown in Table 1:

Table 1. Test results of foamed materials

Water-cement ratio	Curing time/min	Gelation time/min	Uniaxial compressive strength (MPa)			Expansion rate/%
			1d	7d	28d	
1.5: 1	8	20	0.8	1.0	1.2	50
2.0: 1	12	25	0.6	0.8	1.0	125

(2) Material proportioning of bearing layer

The filling material of the bearing layer is the filling support material independently developed by the company, and the main material is made of Portland cement clinker, gypsum, lime and fine aggregate. Aggregate, also known as aggregate, is the main component of concrete, which mainly plays a skeleton role in concrete and reduces the volume change caused by dry shrinkage and wet expansion of cementitious materials in the process of setting and hardening [13]. In this paper, the fineness of aggregate in the filling material is between 0.18 mm and 0.2 mm, which belongs to fine aggregate. Concrete fiber is one of the common materials to improve the crack resistance and toughness of cement-based composite materials/mortar. It can effectively control the plastic shrinkage of cement and the micro-cracks caused by temperature changes, prevent and inhibit the formation and development of primary cracks in concrete, greatly improve the anti-cracking and impermeability of the material itself, and increase the toughness of cement [14].

Through the above theoretical analysis, it can be seen that the foam material of the top layer can improve the compressibility of the filling body, the filling material has better crack resistance, toughness and integrity by adding fiber and fine aggregate to the bearing layer, and the early strength and setting time of the filling body can be improved by adding additives such as early strength agent and accelerator, so as to control the roof movement in time.

The orthogonal test method is used to determine the proportion of each factor (water-cement ratio, dosage of early strength agent, dosage of accelerator, and dosage of fiber), and the best ratio of bearing layer is determined by taking the cementitious time, uniaxial compressive strength (1 d, 7 d, 14 d and 28 d) and reaction temperature as the evaluation index. The level of each factor in the orthogonal test is shown in Table 2:

Table 2. Factor level of orthogonal test

Level	Factor			
	Water-cement ratio	Early strength agent%	Accelerator%	Fiber%
1	0.8:1	0.4	0.3	0.2
2	0.8:1	0.8	0.6	0.4
3	0.8:1	1.2	0.9	0.6
4	1:1	0.4	0.6	0.6
5	1:1	0.8	0.9	0.2
6	1:1	1.2	0.3	0.4
7	1.2:1	0.4	0.9	0.4
8	1.2:1	0.8	0.3	0.6
9	1.2:1	1.2	0.6	0.2

3. SPECIMEN RESULTS AND ANALYSIS

3.1. Test Results

The orthogonal test results of filling materials for bearing layer are shown in Table 3, including the test results of four indexes (initial/final setting time, reaction temperature and compressive strength) under four factors (water-cement ratio, dosage of early strength agent, dosage of accelerator and dosage of fiber) and levels.

Table 3. Results of orthogonal tests

Experiment number	Compressive strength/MPa				Loss of flow/min	Hardening/min	Reaction temperature/°C
	1d	7d	14d	28d			
1	10.2	12.3	14.9	18.3	15.8	31.3	49
2	9.7	13.4	15.3	19.8	13.5	24.3	51
3	15.8	19.2	21.1	23.3	8.8	19.9	56
4	9.4	10.1	12.8	14.4	22.8	38.3	48
5	8.9	10.8	14.2	16.5	12.2	26.2	52
6	9.0	11.3	15.6	17.6	19.5	34.3	47
7	6.3	8.6	9.4	12.2	18.5	36.6	45
8	7.1	9.2	10.2	13.1	32.3	56.9	39
9	6.9	9.7	11.3	14.9	26.8	46.6	42

3.2. Result Analysis

According to the orthogonal test data of the filling material of the bearing layer, the range [15] of the average value of the initial setting time, final setting time, reaction temperature and compressive strength of the material under each factor level is calculated respectively. In order to determine the influence order of the four factors on the test results more intuitively, the main effect diagram of the mean value is made with the level of each factor as the abscissa and the mean value of the test results as the ordinate. The range is calculated as follows:

$$R_j=\max\{\overline{K_{ij}}\}-\min\{\overline{K_{ij}}\}$$

Where: R j is the range; K ij Is the mean value under each factor level; I am the row, representing the influencing factors of the orthogonal test; J is a column representing the level of each contributing factor.

(1) Initial/final setting time of slurry

The initial setting/final setting time of grout is affected by the change of water-cement ratio, accelerator dosage, early strength agent dosage and fiber dosage, and the relationship between them is shown in Fig. 1 and Fig. 2:

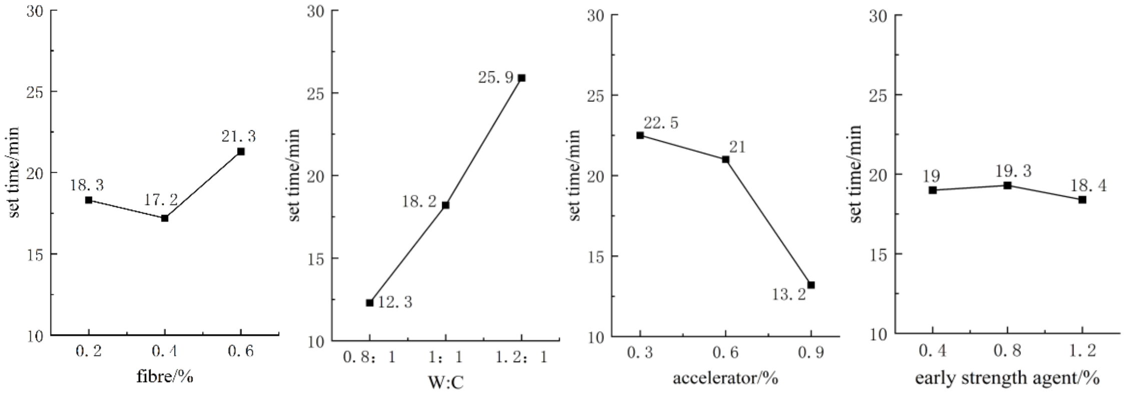

Figure 1. Effect of factors on the mean value of initial setting time

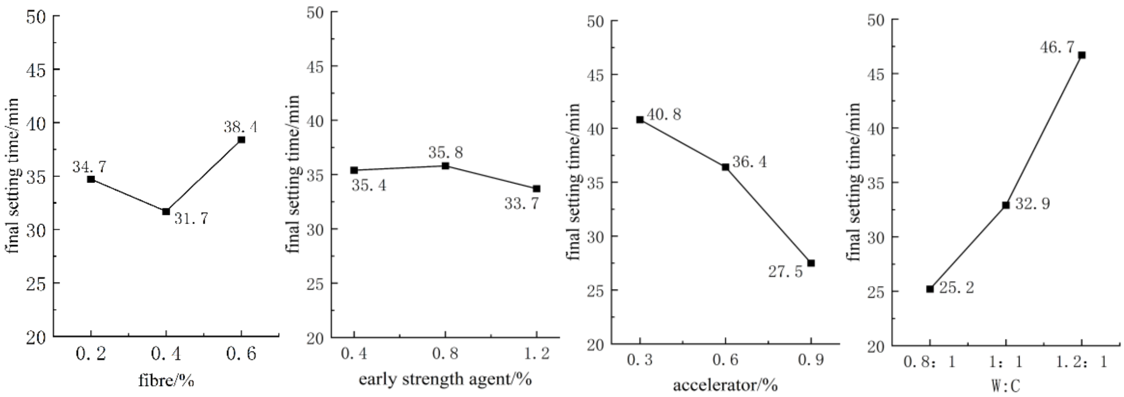

Figure 2. Effect of factors on the mean value of final setting time

It can be seen from Fig. 1 and Fig. 2 that under the test conditions, the initial/final setting time has the following rules:

1) With the increase of water-cement ratio, the initial/final setting time of the slurry becomes longer. This is mainly because the change of water-cement ratio affects the fluidity of slurry, the interaction between particles and the chemical reaction rate, thus affecting the formation process of gel.

2) With the increase of accelerator dosage, the initial/final setting time of grout is shortened. The main reason is that the activator can promote the setting and curing process of cement slurry, reduce the gap between cement particles and improve the initial/final setting time of slurry.

3) The change of the content of early strength agent and fiber has little effect on the initial/final setting time of the grout, and the increase or decrease of these contents within a certain range will not significantly change the setting time of the material.

Taking the initial/final setting time as the index, the range of the water-cement ratio factor is the largest, indicating that the water-cement ratio has the greatest influence on the setting time of the slurry among the four factors. The influence degree of each factor is in the order of water-cement ratio, accelerator dosage, fiber dosage and early strength agent dosage. The setting time of the material is mainly determined by the generation rate and quantity of the hydration products of the slurry, and the network structure formed after the coagulation makes the slurry harden gradually [15]. Compared with the high-water material, the setting time of the material is more controllable by adjusting the water-cement ratio, which can relieve the pressure of the filling template and prevent the material from collapsing in the bag and causing site losses.

(2) Reaction Temperature

The reaction temperature of the material refers to the temperature change of the slurry during the curing process. The reaction temperature of the slurry has an important impact on the strength development, crack formation and other properties of the sample. The reaction temperature of the material varies with the water-cement ratio, the amount of accelerator, the amount of early strength agent and the amount of fiber, as shown in Figure 3.

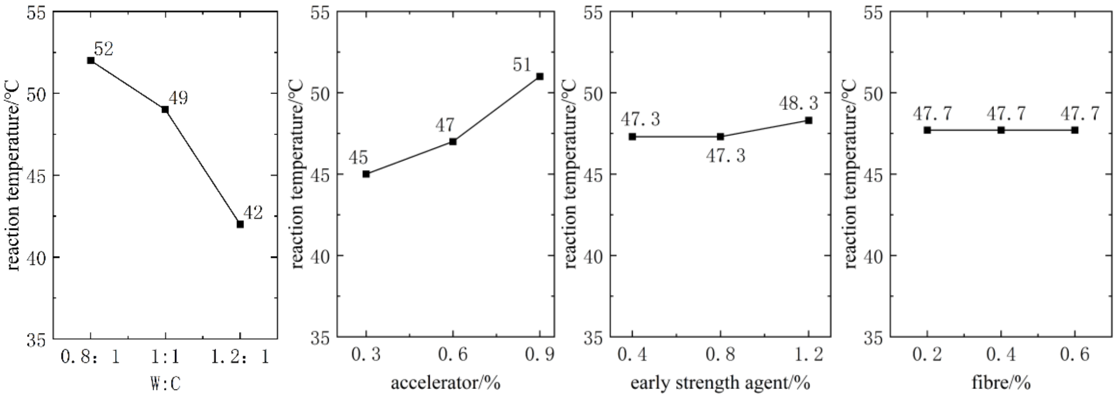

Figure 3. Effect of factors on the mean value of reaction temperature

It can be seen from fig. 3 that under the test conditions, the slurry reaction temperature has the following rule:

1) With the increase of water-cement ratio, the reaction temperature of slurry decreases. This is because water plays the role of dilution and heat dissipation in the hydration reaction of slurry. Increasing the content of water can slow down the hydration reaction and absorb more heat, thus reducing the reaction temperature of slurry.

2) The reaction temperature of the grout increases with the increase of the accelerator dosage. Because the addition of the accelerator can accelerate the hydration reaction and make the heat release faster, the reaction temperature of the slurry will rise accordingly.

3) The change of the dosage of early strength agent has little effect on the reaction temperature of the grout, which shows that the reaction temperature of the grout increases slightly with the increase of the dosage of early strength agent. The early strength agent improves the early strength of the sample mainly by improving the crystal structure between cement particles and promoting the hydration reaction, and does not release more heat by accelerating the hydration reaction like the accelerator, so the increase of the dosage of the early strength agent usually does not significantly affect the reaction temperature of the slurry.

4) Observe Fig. 3. With the increase of fiber content, the mean value of slurry reaction temperature is a constant value, indicating that fiber content has no effect on the reaction temperature.

Taking the reaction temperature as the index, the range of the water-cement ratio factor is the largest, indicating that the water-cement ratio has the greatest influence on the reaction temperature of the material among the four factors. The influence degree of each factor is in the order of water-cement ratio, accelerator dosage, early strength agent dosage and fiber dosage.

(3) Compressive strength

The compressive strength parameter of the sample is one of the main technical indexes of grouting materials, which is affected by many factors (water-cement ratio, aggregate, curing conditions, mix proportion, construction technology, sample

Proportion, observe the change of compressive strength of the sample, and the relationship between them is shown in Figure 4:

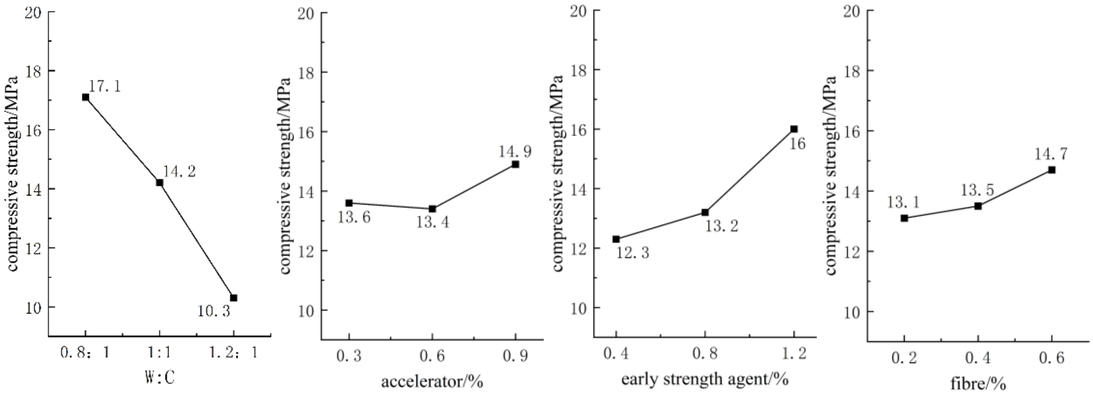

Figure 4. Effect of factors on the mean value of compressive strength

It can be seen from Fig. 4 that the compressive strength of the sample has the following rule:

1) With the increase of water-cement mass ratio, the compressive strength of the sample has an obvious downward trend. When the water-cement mass ratio increases, the water content in the slurry increases relatively, which will lead to the decrease of the compactness of the concrete. If the water-cement ratio is too high, the water-cement ratio will increase, which will lead to the increase of the voids in the sample, thus reducing the compressive strength of the sample.

2) With the increase of the content of early strength agent, the compressive strength increases gradually, because the addition of early strength agent can promote the hydration reaction of cement, accelerate the setting and hardening process of the material, thereby improving the early compressive strength of the material, and from the curve, when the content of early strength agent is 0. 8%, the compressive strength of the sample increases significantly with the increase of age.

3) The compressive strength of the backfill samples can be improved by adding fiber into the material. With the increase of the fiber content, the compressive strength of the samples shows a gradual increasing trend. On the one hand, the fiber can effectively inhibit the crack propagation of the material and improve the crack resistance of the sample; On the other hand, the addition of fiber can improve the toughness of the sample and make it more durable when stressed.

4) Accelerators usually have a certain impact on the compressive strength of materials. In some cases, the use of accelerators may lead to an increase in the early strength of the specimen, because the accelerators can promote the hydration reaction and accelerate the solidification and hardening process of the specimen.

Taking the compressive strength as the index, the range of the water-cement ratio factor is the largest, which indicates that the water-cement ratio has the greatest influence on the reaction temperature of the material among the four factors. The influence degree of each factor is in the order of water-cement ratio, early strength agent dosage, fiber dosage and accelerator dosage.

Through comprehensive comparison of the four indexes, it is found that in the optimal scheme meeting the requirements of roadway retaining engineering, the water cement ratio is 0.8: 1, the amount of early strength agent is 1.2%, the amount of accelerator is 0.9%, and the amount of fiber is 0.6%. The above analysis shows that the third group of samples of the bearing layer has the characteristics of quick setting and early strength, the initial setting time is within 9 minutes, the final setting time is 19.9 minutes, the early compressive strength is 15.8 MPa, and the maximum compressive strength in the later period is 23.3 MPa.

4. SAMPLE SUPPORT PARAMETER DESIGN

By applying different support methods (through steel bar, steel bar ladder beam, steel bar mesh) to the samples to simulate the actual underground compression process, the influence of different support conditions on the peak stress (compressive strength, residual strength), deformation resistance and integrity of the samples was studied.

The sample size is 90 mm × 90 mm × 90 mm, different supporting methods are applied to the side of the sample, and the curing age is 7 days. The uniaxial loading mode is adopted for the sample, the axial loading rate is 0.02 mm/s, and the different lateral reinforcement methods are shown in Table 4:

Table 4. Test program for different support methods for specimens

Number	Cross rebar		Reinforced ladder beam		Steel mesh	Remark
	Number of roots	Spacing	Number	Row spacing		
D-1	0	— —	——	——	——	Integral bearing layer material
D-2	0	——	——	——	——	2mm foam material at the top and bearing layer material at the bottom
D-3	9	23	——	——	——	Same as D-2
D-4	9	23	6	23	2	Same as D-3

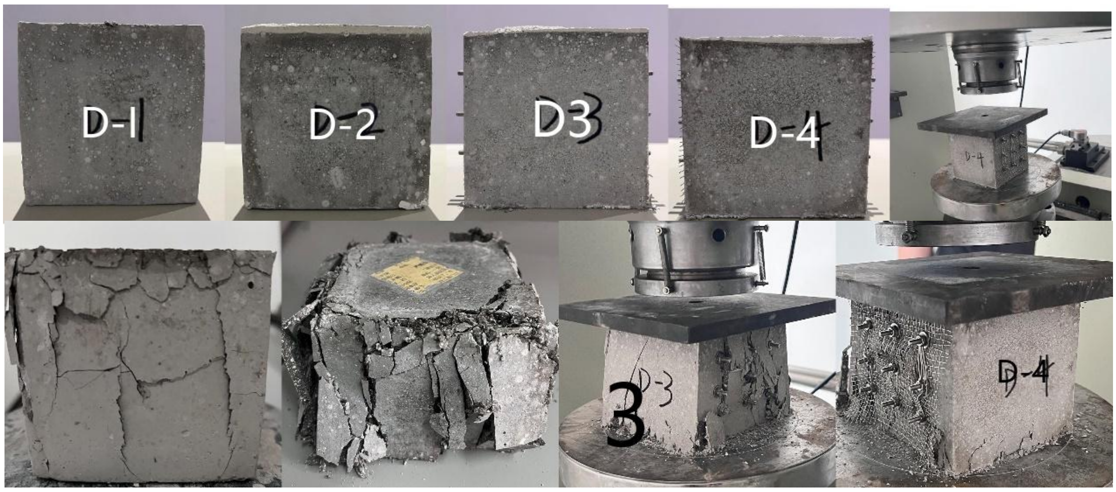

Figure 5. Morphological characteristics of specimens before and after loading

The distribution of failure modes and the stress-strain curves after failure are shown in Fig. 5 and Fig. 6. The stress-strain curve reflects the mechanical properties and fracture characteristics of the material. On the stress-strain curve, the yield point, the maximum stress point, the fracture point and other characteristics of the material can be observed, so as to analyze the strength, toughness and ductility of the material.

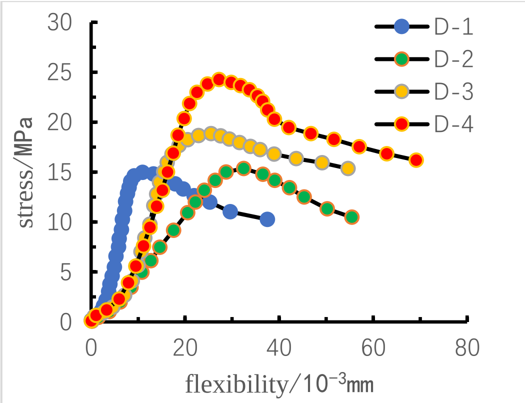

Figure 6. Stress-strain curve of specimen

By observing the top and middle parts of D-1 group specimens, it was judged that the specimens were subjected to tensile failure and shear failure at the same time, resulting in a complex internal stress state, in which shear failure was the main failure form, and the stress-strain curve of shear failure usually showed a linear increase of stress with strain, without obvious necking phenomenon. In the process of loading, the specimen gradually accumulated strain and reached the peak stress of 14. 9 MPa, and finally cracked.

Because of the addition of foam material and fiber, and no reinforcement measures of tensile anchor and steel mesh, the compression morphology of D-2 group samples obviously shows strong plasticity, which ensures the stability of the samples after failure. It can be seen from the curve that the material still has a residual strength of 12.1 MPa after failure, and after reaching the yield point, the strain gradually increases while the stress remains relatively stable.

The peak stress of D-3 sample before failure is 18. 7 MPa, which is increased by 20. 3% compared with 14. 9 MPa of the blank group. It is observed that the failure positions are mainly distributed on one side of the opposite-pulling anchor rod, and the shear failure occurs along the vertical direction of the opposite-penetrating steel bar. This is because the opposite-penetrating steel bar is a rigid material with high strength and rigidity, and a large binding force is applied to the sample in the test process, so that the sample is subjected to a local concentrated force. Resulting in shear failure of the specimen in the vertical direction on the side opposite to the steel bar.

After the D-4 group specimens were loaded with 9 steel bars, 6 steel ladder beams and 2 steel meshes, the surface of the specimens was basically not damaged, and the deformation occurred on the side of the steel ladder beams and the steel meshes. The peak stress is 24.3 MPa and the residual stress is 17 MPa.

To sum up, the addition of foam material and fiber improves the yielding characteristics and plasticity of the filling body, so that the sample still has a large residual strength after failure. After the support combination is applied, the compressive strength of the sample is greatly improved, and the overall stability of the sample cannot be guaranteed only by adding the tension reinforcement, so the lateral restraint of the reinforcement mesh and the reinforcement ladder beam is needed to ensure that the stress concentration does not occur when the sample is stressed. The test failure results, such as D-4, show that there is no cracking, crushing and large deformation on the surface of the sample, and its integrity and stability are improved.

5. ENGINEERING APPLICATION

5.1. Project Overview

The 11102 working face of Seshui Coal Mine is located on the left side of the haulage inclined roadway in the north wing section of the mine, with a strike length of 400 m and a dip length of 120

m. The C11 coal seam is mined, with a thickness of 1. 07 ~ 3. 26 m, an average thickness of 1. 52 m, and a buried depth of about 300 m, belonging to a nearly horizontal coal seam. The lithology of the roof is silty mudstone intercalated with medium-thick layered siderite, of which the immediate roof is mudstone with a thickness of 1 ~ 2m, and the basic roof is siltstone with a thickness of 13 ~ 14m. After coring, the tensile strength of the basic roof is 3.1MPa, and the compressive strength is 63.7MPa. It is a hard roof that is not easy to fall.

5.2. Top-Cutting Pressure Relief Scheme and Parameters

According to the geological conditions of Seshui Coal Mine and the actual construction conditions, the roof cutting height of 6 meters and the roof cutting angle of 15 degrees were determined, and the transportation roadway of 11102 working face was cut off. From the open-off cut to the terminal mining line, the presplitting drilling blasting was carried out 50 meters ahead of the working face, with the drilling diameter of 42 mm and the hole spacing of 600 mm [16, 18]. Roadside gangue retaining support and temporary roadway support shall be erected at the end of the working face in time. After the working face is advanced, the support scheme of temporary single column + roadside filling wall in the roadway shall be adopted for the maintenance area behind the working face.

5.3. Roadside filling process and parameters

(1) Filling materials and equipment

Foaming material is selected for the top 300 mm of the roadside filling material, and the water-cement ratio is 2. 0:1; the bearing layer is selected as the third group of the best scheme. Compare with that traditional concrete pouring material and the high-water material, the single-liquid prop material has the advantage of single pipeline transportation, long underground transportation distance, simple process, lower strength than the concrete material and higher strength than the high-water material; A special structure of that fil body is provided with a yielding top lay and a filling layer, the expansibility of the material of the yielding top layer play a role in active roof contact and yielding, and the filling layer positioned below the yielding top layer has certain strength and plays an important bearing role during secondary mining of the retained roadway.

Filling equipment adopts screw filling pump, which can realize long-distance (100-500m) continuous pumping construction, and the equipment can fix the water-cement ratio, mix and transport at the same time, continuous construction, compared with the filling process of high-water materials, the single-component material pulping process is simple, which can reduce underground labor intensity and improve filling efficiency.

(2) Hanging and filling of soft mold bags and reinforcement measures

The filling retaining wall beside the roadway is realized by "soft mold bag + filling material", that is, a retaining wall with a length of 4000 mm, a width of 1000 mm and a height of 3100 mm is constructed at the back of the working face along the roadway direction and 300 mm away from the roof cutting line. The filling pillar material has the characteristics of quick setting and early strength. The soft film bag is used to reduce the quantity of formwork erection. The material has sufficient strength, antistatic and flame retardant properties. The processing joints are firm and reliable. The shape meets the requirements of each filling and hanging.

With the actual mining of the working face, the constructed roadside support body will bear the load transferred by the immediate roof and the basic roof, and bear the lateral caving pressure in the process of roof rotation after the breakage of the basic roof, thus forming a higher abutment pressure behind the working face, leading to the generation, development and transfixion of fissures, greatly affecting the integrity and bearing capacity of the filling body, and leading to the sharp reduction of the working space. And threaten safe production [17]. Therefore, measures must be taken to improve the strength and overall stability of the filling body. Before filling, the filling bag can be pre-threaded with tensile steel bars made of threaded steel, and after the filling body is solidified, a certain force to restrain lateral deformation can be applied.

(3) Slurry delivery

A filling area is selected, roof support is carried out in the filling area, a filling bag is hung, the top is well connected, and in the process, in order to prevent the soft film bag from expanding and deforming, a reinforcing mesh is laid around the bag to form certain restraint; The single column is used as the filling body to bear most of the pressure of the overlying strata. During the period of material loss of flow, the tensile anchor rod is driven to improve the compressive strength and integrity of the filling body. After 4 hours, the strength can reach 9 MPa, which is enough to bear part of the pressure of the roof. After the completion of material formwork erection, the filling pump is used to transport the slurry for tight filling.

5.4. Effect of Gob-Side Entry Retaining

Mine pressure monitoring points shall be arranged in the retained roadway, and one monitoring station shall be arranged at 20m, 50m, 80m and 120m away from the open-off cut, numbered as 1 # station, 2 # station, 3 # station and 4 # station in turn. Each station shall be equipped with roof separation monitor, anchor cable dynamometer and single column pressure dynamometer, and the surface displacement of the single column shrinkage meter roadway shall be monitored at the same time. The monitoring effect is based on the monitoring results of 1 # observation station after mining 20m, and the observation is carried out in turn every day during the mining of the 11102 working face, and once a week during the suspension of mining.

The surface deformation and roof subsidence of the roadway are shown in Fig. 9, and the working resistance of the single support of the temporary support is shown in Fig. 10:

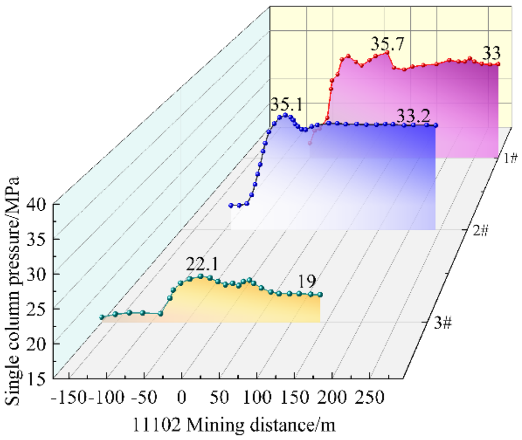

Figure 9. Tunnel Displacement Monitoring Curve

It can be seen from the monitoring deformation curve in Fig. 9 that the overall deformation of the roadway is not large, the maximum convergence of the two sides is 40mm, and the maximum convergence of the roof and floor is 202.8mm, which is mainly reflected in the roof settlement, and the roof settlement is 139mm. At 90m behind the working face, the convergence of the two sides suddenly increases, which is caused by the impact of roof caving on the gangue retaining system. The convergence of the roof and floor begins to increase slowly at 35m behind the working face and tends to be stable at 100m behind the working face.

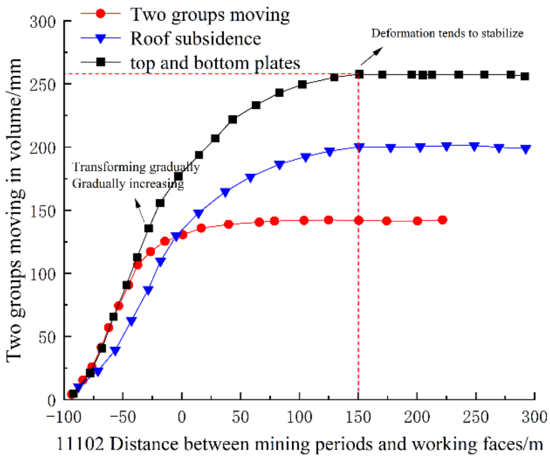

Figure 10. Single Column Pressure Monitoring Curve

As shown in Fig. 10, with the advance of the working face, the pressure of the single prop gradually increases, and at 110m behind the working face, the pressure value begins to stabilize, and with the continuous advance of the working surface, there is a small fluctuation in the pressure value. The main reason is that the stress of the roadway roof changes in the process of rebalancing the stress of the rock stratum behind the working face. At 80 m behind the working face, the pressure reaches a peak value of 23 MPa, and the final stress stabilizes at 18 MPa.

The actual effect of roadway retaining is obvious, and the scene pictures are as follows:

Figure 11. The effect of retaining roof

6. CONCLUSION

(1) The performance experiment of roadside filling material was carried out by means of orthogonal test, and the optimal material ratio was obtained by range analysis method. Under this ratio, the hydration reaction temperature of sample slurry was 56 °C, the flow loss time was 8. 8 min, the hardening time was 19. 9 min, and the average compressive strength of 14 d reached about 21 MPa.

(2) After the design of support parameters, it is found that under the optimal support conditions, the surface of D-4 sample does not appear cracking, crushing and large deformation, the peak stress reaches 24. 3 MPa, and there is a large residual stress.

(3) Aiming at the practical engineering application of roadside filling in gob-side entry retaining for roof cutting and pressure relief in 11102 working face of Seshui Coal Mine, the roof cutting height

of 6 meters, the roof cutting angle of 15 degrees and the blasting spacing of 600 mm were determined. The top of the filling material is made of foam material, the bearing layer is made of single liquid pillar material, and the corresponding filling equipment and technology are matched, which solves the problems of complex filling system and high labor intensity of the traditional filling material. The field application and monitoring results show that the effect of roadway retaining is good, which can be used for 11104 working face mining.

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